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Revision	Basic

6700 Division Work Instruction

Science Concept Formulation - Path to the Science Concept Review

Approved by Chief, Microgravity Science Division,6700

NASA - Glenn Research Center
Cleveland, OH 44135

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1.0 INTRODUCTION

1.1 PURPOSE

This work instruction provides the steps necessary to advance a Flight Definition project from grant initiation to the Science Concept Review (SCR), i.e. through the Science Concept Formulation (SCF) phase. The typical time required to reach the SCR is 24 months after the grant has been awarded. However, this timeline may vary because each project will have a different level of science maturity when the proposal is selected, including those using existing flight hardware; furthermore not all tasks listed here may apply exactly. (A list of acronyms used in the report is provided in Appendix A).

1.2 SCOPE

This work instruction is for Project Managers, Project Scientists, and technical teams that perform microgravity research projects at the Glenn Research Center. This document applies to projects as of April 15, 1999.

2.0 REFERENCES

2.1 REFERENCE DOCUMENTS

Document Number	Document Title
NPG 7120.5A	NASA Procedures and Guidelines "NASA Program and Project Management Processes and Requirements"

2.2 APPLICABLE DOCUMENTS

Document Number	Document Title
GRC-P6700.000	Organizational Objectives and Responsibilities
GRC-P6700.003	Microgravity Research Formulation
GRC-W6700.017	Quality Function Deployment
GRC-W6700.012	2.2 Sec Drop Tower Requirements and Procedures for Payload Testing

Document Number	Document Title
	Zero-G Facility Document
	KC-135 Document
GRC-W6700.014	MSD Payload Planning Process
GRC-W6700.011	Microgravity Research Archival Implementation Plan

2.3 RECORDS AND FORMS

NASA-HQ NRA Selection Letter to PI

PI Proposal

QFD Final Report

Draft SRD – SCR Version (typically second draft of preliminary SRD)

SCR Attendance Sheet

Science Review Panel's Letter of Recommendation

Science Evaluation letter from NASA HQ-Director of the Microgravity Research Division

Authority to Proceed to RDR letter from Microgravity Research Program Office

3.0 SAFETY PRECAUTIONS

Safety practices with GMI's and Users' Guides specified above.

4.0 TOOLS, EQUIPMENT AND MATERIALS

It is anticipated that the Glenn Research Center's (GRC) combustion and fluids' laboratories and its low-gravity facilities will be utilized. In addition, the JSC KC-135 may also be used.

5.0 PERSONNEL TRAINING AND/OR CERTIFICATION

For the engineering team, experiment manager, project manager, and phase A manager: B.S. or advanced degree in engineering, mathematics, physics or computer science.

For project scientist: M.S. or Ph.D. in engineering, mathematics, chemistry, biology, or physics.

6.0 INSTRUCTIONS

6.1 ROLES AND RESPONSIBILITIES

Preparing for a Science Concept Review is a team effort. It is the Project Scientist's (PS) responsibility to adequately prepare the Principal Investigator (PI) for a successful SCR. The primary tasks of the PI in the Science Concept Formulation (SCF) stage is to write a thorough Preliminary Science Requirements Document (PSRD) and conduct research to resolve science concept feasibility issues. The PS may assist the PI in the development of the science requirements, laboratory testing and/or numerical analyses. The PS leads the NASA Science Concept Formulation effort and plans the overall direction of the project which may be “tailored to meet the specific needs of the project given driving characteristics such as size, complexity, criticality, and risk,” (see NPG: 7120.5A, Chapter 3, Project Formulation). The PS is supported by the Phase A Manager who is responsible for assembling the engineering team, training them in the Quality Function Deployment (QFD) process and conducting QFD (please see the “The Application of QFD…” document). The Experiment Manager (EM) also supports the PS by being responsible for developing task statements for the engineering team, the budget, and the day-to-day schedule. The engineering team will formulate experiment concepts, build and test breadboards, and review the Preliminary SRD. A Project Manager (PM) is assigned to the project about 6 to 7 months prior to the SCR to learn about the experiment and prepare the SCR engineering presentation. The PS is responsible for the scheduling and holding of the SCR with the consent of the PI, the PS’s supervisor, the EM, and Headquarters’ (HQ) Enterprise Discipline Scientist (EDS). The Enterprise Discipline Scientist (EDS) selects the Science Review Panel for the SCR and conducts the Review. A Deputy Project Scientist (DPS) may be assigned to the project to be trained by and assist the PS. A Flow Chart of the roles and responsibilities is provided in Section 7.

The PS must authorize the most cost-effective and timely approach to satisfy the PI’s requirements which usually means guiding the PI to establish the minimum level of complexity of an experiment which can accomplish the PI’s approved objectives. Specifically the PS is to assist the PI in:

1. Assuring the objectives of the flight experiment can be traced to specific statements in the peer-reviewed, original proposal and are consistent with the letter awarding funding for the proposed effort.

2. Defining the minimum operational and measurement requirements for the experiment. If the performance of the experimental design or hardware does not meet any minimum requirement, there is sufficient justification for refusal to approve the experiment for space flight.

3. Defining a prioritized list of additional operational and measurement desires which would enhance the scientific return on investment. It is the accepted intent of the PS and the EM to try to develop a feasible design for spaceflight hardware that meets or exceeds these desires.

And to assist the PI and EM by:

4. Providing examples of previous experiments, ground-based experience and available technology believed to satisfy at least some of the requirements.

5. Recommending and/or selecting the best ground-based, low gravity facility or facilities in which to perform experiments to support the conduct of a Science Concept Review.

6. Participating in the trade-off studies and assessment to identify possible carriers (e.g., Fluids and Combustion Facility, Glovebox, Hitchhiker, Sounding Rocket, etc.).

7. Serving as a focal point for communication between the PI and the EM/PM, particularly with respect to clarifying requirements and evaluating interpretations of these requirements.

8. (optional) Providing to the PI, EM, and Microgravity Research management an independent assessment prior to SCR of the need for space flight and the readiness for an SCR.

6.2 PURPOSE OF SCIENCE CONEPT FORMULATION (SCF)

The primary purpose of the Science Concept Formulation phase is to establish a very clear scientific goal(s), approach, and feasibility of the science concept. This includes definition of the overall scope of science to be attempted in the space-based experiment, and the establishment of specific theoretical hypotheses from which are derived the detailed objectives of the experiment (this must be consistent with the scope outlined in the peer reviewed and approved proposal). The preliminary science requirements must be developed to meet the objectives. These requirements specify the initial operating conditions of the experiment, and what is to be measured and how precisely it is to be measured. In addition, it is necessary to establish the feasibility of the conditions and of making such measurements. (To gain a more complete understanding of science requirements please see Appendix B.) Basically, there should be a clearly visible, objectively verifiable "path" from the phenomena to the mathematical model for the phenomena, to the hypothesis to be tested, to the specific measurements required, to the accuracy, precision, data rates, total data points, etc. specified for those measurements. The project must have a clear completion point and always be traceable to the objective of the space experiment. During SCF, science concept feasibility issues or questions that surface must be resolved. For example, does the experiment violate any laws of physics? Does the science concept appear viable? Also, the engineering feasibility issues need to be identified and often emerge when figuring out how to meet the science requirements.

Addressing the viability of the evolving science requirements is generally established through ground-based tests in the PI's lab or in NASA's ground based facilities. Science requirements, may include for example: levels and stability of heat flux, flow rate, temperature, solidification growth rate, species concentration, acceleration, optical imaging, radiant emission, pressure, force, etc. The engineering team may support the PI in establishing the science concept feasibility by designing and developing bench-top hardware (breadboards) and rigs for laboratory and low-gravity tests. To conduct reduced gravity tests please see the appropriate Facility Document (2.2 Second Drop Tower, Zero-G Facility or KC-135) listed in Chapter 2 of this work instruction. In addition to the engineering team, the PS and EM usually assist in laboratory testing if NASA facilities are used. For critical ground-based experiments the PI might provide a well-defined test matrix. The engineering team is encouraged to build useful hardware "quick and cheap" to enhance incremental learning rather than elaborate and sophisticated systems. Also, engineering team support to resolve engineering feasibility issues, which often requires more elaborate breadboards, primarily occurs after SCR.

Except by agreement with the PS, communications by the engineering team with the PI or his representative should be coordinated through the PS. Exceptions can be made upon agreement with the PS. The PI may designate a representative with whom the engineering team may communicate directly. However, it is important for the PI to participate directly with the team by visits and/or telecons as needed. This arrangement can expedite hardware development and allows the PI to focus on key science issues, but requires extensive communications to ensure everyone is up to date on progress and issues.

6.3 THE PURPOSE OF THE SCIENCE CONCEPT REVIEW

The purpose of the SCR is to establish, through peer-review, that the scope and feasibility of the experiment have been adequately addressed to propose a definitive flight experiment. The primary objectives of the SCR are to:

1. Affirm the merit of and need for the experiment (value to the scientific community), establish the detailed scientific objectives, confirm the rationale for a microgravity experiment, justify the use of space-based laboratories for the microgravity environment, and review the proposed scope and experimental approach. In addition, assess maturity, priority, and completeness of the preliminary science requirements to meet the objectives, and confirm that scientific feasibility has been completely demonstrated. The information for the review panel to make these judgments is presented by the PI.

2. Identify the PI's plan of activity with specific milestones between SCR and the Requirements Definition Review (RDR) with the goals of finalizing science requirements, improving models or theories, conducting additional ground-based experiments and completing technology development. (Often the plan proposed at SCR needs modification based on the panel's input provided at this review). The PI presents this information.

3. Evaluate proposed space-based experiment concept (block diagram level) with emphasis on compatibility with science requirements and identify engineering feasibility issues. This information can be presented in both the PI and PM presentations with their respective viewpoints.

4. Define engineering plans (emphasizing the most critical, costly and difficult tasks) to develop the experiment concept into flight hardware (cartoon flight concept may be presented). Prepare the schedule and budget to reach RDR in reasonable detail, and provide rough order of magnitude budget and schedule estimates to flight. The PM presents this information, and may choose to have the EM give part of this presentation.

The SCR generally requires one full day of presentations. The contents of a typical SCR are outlined in Appendix C. The decision-making group at the SCR is the Science Peer Review Panel and the NASA HQ Enterprise Discipline Scientist. As described in the MSAD Management Plan: "The Science Peer Review Panel will consist of qualified scientists in the field, including members from previous review panels with prior knowledge of the experiments as appropriate. The Program Scientist (Enterprise Discipline Scientist) will act as an ex-officio member of the Science Review Panel. This panel will review the science requirements to determine their scope and maturity, and verify the need for the microgravity environment. They will also review the results of the science feasibility demonstrations and the explicit experiment which is being proposed. They will review the emerging conceptual hardware design to identify engineering feasibility issues to be addressed during the Hardware Definition Phase (Engineering Concept Formulation)." (For the complete Science Review Panel Charter please see Appendix G). The PS may be asked for an independent opinion on the readiness of the experiment for flight. The PS may augment the list of needed activities between SCR and RDR, highlight areas of greatest concern, identify specific questions for the peer panel to address, etc.

The SCR shall be conducted within four years after proposal selection. If a consensus is reached between the PI and PS that more than four years is needed to reach the SCR, the Enterprise Discipline Scientist (EDS) should be contacted for a decision on the next appropriate action. In all likelihood, the engineering team will be disbanded and the grant or contract will be maintained and monitored as if it were a ground-based research study.

A well defined and clearly written Science Requirements Document (SRD) is crucial for a successful SCR. The SRD, written by the PI for both peer scientists and engineers, describes the scientific justification, the objective, the need to conduct the experiment in microgravity, and the necessary science requirements for the experiment. (The definition and explanation of science requirements is provided in Appendix B). The SRD does not, however, contain detailed concepts or engineering drawings of the proposed experiment. After SCR it is the role of the engineering team to meet the science requirements using concepts and hardware of their choosing; this information can be documented in an experiment capabilities document. However to facilitate the design, approaches to meet the science requirements may be suggested in the SRD. If adapted, these suggestions to meet science requirements need to be verified by the engineering team. The PS, EM, PM, and engineering team must review the SRD (several drafts), and provide feedback to the PI for modifications. The PS must ensure it is written properly and is complete. Appendix D provides a recommended table of contents for the SRD, and Appendix E gives an example of the signature page found in the SRD. This page is signed by the appropriate individuals when all the requirements have been agreed upon; usually after RDR.

From grant initiation to SCR, the PS controls the experiment definition activities when the work is largely scientific, e.g. identifying the science requirements. The preliminary engineering feasibility issues, usually identified through the QFD process, are typically the responsibility of the EM up to the SCR. Although not essential, it may be advantageous to resolve some of the most critical engineering feasibility issues before SCR. After the SCR, the PM is responsible for resolving all of the engineering feasibility issues and controls the project from this point on. However, through RDR, the science requirements are being refined. It is the responsibility of the PS to inform the PM of any changes in the science requirements. After SCR, the Preliminary SRD usually needs to be revised only one more time before RDR. However, through laboratory testing at GRC and studying vendor's hardware specifications, the PS, PM, and the engineering team will assess and may suggest changes to some of the PI's science requirements and test matrix. Therefore, it is very common and useful for the PI to update the Science Requirements Summary Table and the Test Matrix as many times as needed prior to RDR.

6.4 TASK LIST

The following is a typical list of tasks encountered to reach the SCR for a flight definition project; this list will vary for each project. For example, for fast track projects, this schedule may need to be accelerated or reduced in scope (such as one draft of the Preliminary SRD before the SCR instead of two). Note: The Block numbers refer to the numbers listed on each block given in the flow chart in Section 7.

Just after Proposal is Selected by the NASA Research Announcement (NRA) Review Process: (Blocks 1-4)

Microgravity Research management assigns a PS and Phase A Manager. The PS reads the proposal, NASA Headquarters letter of award, NRA science and engineering review panels' comments and criticisms (if available), and prepares and submits for processing the grant or contract package. The Phase A Manager also reads the proposal, and with the first line supervisor assembles the engineering team. The team reviews the proposal.

About One to Two Months after Grant or Contract Award: (Block 5)

The Principal Investigator's kick-off meeting is held. The Phase A Manager, PS, EM, and engineering team attend the meeting; in addition the PS and Phase A manager are encouraged to invite others (e.g. diagnostics' specialists) who can contribute to the kick-off meeting. The PI gives a presentation to the team, which includes the scientific objectives, goals, motivation, challenging areas, and completion point of the experiment. Especially important in the presentation by the PI is the relevant experimental technique with which he thinks his objectives can be met. The engineering team makes their first assessment of the most challenging elements of the experiment. Questions and discussions are as important as the presentations. This meeting represents the first opportunity to appreciate what each party (PI and team) brings to the experiment. The outcomes are PI-orientation to the NASA process, and project team skills assessment and alignment, initial task definitions and assignments, and guidelines for ongoing communication practices. After the meeting the PS gives a copy of the typical SRD table of contents (Appendix D) and examples of SRD's and SCR's to the PI. While it is important for the project to be flexible at this point, it is the responsibility of the PS to ensure that the PI adheres to the spirit and, as far as possible, the statement of the original proposed experiment. The selection of flight projects is based, in part, upon an assessment of the likely cost of the experiment. Consequently, it is inappropriate for the scope of the program to change dramatically from the proposed level unless this growth is directed by the EDS.

About Three to Four Months after Grant or Contract Award: (Blocks 6-9)

The PI shall produce a “Zeroeth Draft” of the Science Requirements Document which consists of the following: the table of contents, executive summary, experiment objective, preliminary list of science requirements, the preliminary test matrix, and the post-flight data deliverables. (An example of the Zeroeth Draft is found in Appendix H. Also, the definition of a science requirement is found in Appendix B.) To improve the quality of the “Zeroeth Draft” it is especially helpful for the PS to work with the PI to define the methods by which all data to be collected in space flight will be reduced and interpreted. Deferral of this step has proven to be problematic throughout the life of the project.

Upon receipt of the “Zeroeth Draft”, the PS and Phase A manager start team meetings to determine the key science concept feasibility issues by employing the Quality Function Deployment (QFD) process with the engineering team and PI. (The PI usually participates via telecon.) The Zeroeth draft is used as a starting point for the QFD process. QFD is conducted by the Phase A Manager and is a method to derive requirements and identify feasibility issues that need to be solved for successful implementation of the experiment (see “Application to QFD…” Document). Note that QFD is only conducted if needed for a given project. Even at this early stage, the PS and engineering team begin thinking about tradeoffs in order to determine the most probable selection of a recommended carrier for the spaceflight experiment. At the end of the QFD process, the PI, PS, the EM and project team determine who will be responsible for each development issue. The Phase A Manager will begin reporting the overall status of the project at the Discipline (Combustion and Fluids) Program Review. The Phase A manager, EM and PS will begin monthly reporting of project and science status to the Discipline Program Manager and first line supervisors.

About the Fifth and Sixth Months after Grant or Contract Award: (Blocks 10-12)

The QFD process continues until completed. Ideally, the PI also drafts the success criteria for the spaceflight experiment for review by the PS and the engineering team. The entire QFD process requires 3 to 6 months including brainstorming solutions to feasibility issues. At its conclusion, important science concept feasibility issues (e.g., issues that justify a long duration microgravity experiment), engineering and technology issues, and experiment concepts are identified. Through the QFD process the engineering team rapidly comes to a detailed understanding of the proposed experiment, and the PI begins to focus on what can and cannot be done cost effectively. A QFD final report is written as a group effort by the team, EM, PS, and Phase A Manager and is assembled by one of the engineering team members. The QFD report outlines the science requirements, science concept feasibility issues, the design, fabrication, testing and analyses, that must be accomplished before SCR and who (project team or PI) will be responsible for each development issue. A summary of this report is presented to Microgravity Research management by the PS. The EM will derive a draft plan to SCR based on the QFD final report. This plan identifies NASA's portion (which includes the engineering team) of the work, responsibilities and overall approach to reach SCR. The plan typically includes the experiment objectives and deliverables, definitions and goals of tests and analyses, and schedule and budget.

About Seven Months after Grant or Contract Award: (Blocks 13-20)

After QFD, breadboard development begins on the most critical elements at the PI's lab (university) and/or at GRC's laboratories. The critical elements must be targeted to resolve science concept feasibility issues. For experiments to be conducted at, the PI or PS prepares a test plan with concurrence from the EM. The EM then leads the engineering team (e.g. develops task statements for breadboards). The engineering team formulates experiment concepts, builds breadboards and conducts tests. The PS and EM conduct lab tests with the engineering team to address critical elements and clarify science requirements as they evolve. Based on results, the PS works with the PI, EM and team to revise requirements, concepts, and/or test matrix. Breadboard activity continues through SCR. Also, the PS continues telecons between PI and team as necessary. The engineering team continues to develop breadboards and/or ground-based, low-gravity hardware to be tested at the Glenn Research Center, or in some cases, may develop breadboards to be tested at the PI's University. (To conduct reduced-gravity tests please see the appropriate facility documents (2.2 Second Drop Tower, Zero-G Facility or KC-135) listed in Chapter 2 of this work instruction). The PS should have an understanding of all tests conducted. Often the PI's students or associates may come to GRC during this phase of the effort. (In the case of a non-US citizen or non-permanent US resident, a NASA C-216 Non-U.S. Citizen Access Request Form must be completed and sent to the Security Branch at least 30 days prior to the onsite visit.) If ground-based, low gravity testing is required, the schedule to SCR may need to be extended significantly; it may require more than two years after grant or contract award to reach SCR. The PS begins to guide the PI in the writing of the first complete draft of the Preliminary SRD. Regular weekly meetings begin with the EM, PS, and engineering team. For the Phase A manager these meetings are optional.

Seven Months Prior to SCR: (Blocks 21-29)

The Project Manager is assigned to the project around this time period. The PI shall deliver the first complete draft of the Preliminary SRD; the PS must read it carefully for content and format. In a few cases, such as when the PI is a theoretician, a Co-Investigator (Co-I) or Post-Doctoral Fellow with an experimental background, or the PS, may write parts of the Preliminary SRD, such as the experimental procedure and science requirements sections. In general, the PS should only provide comments to the Preliminary SRD, not write it. (It is critical that the PI retains total ownership of the experiment.) The EM, PM and the engineering team also read the preliminary SRD and provide comments and suggestions for the second draft to the PS. The PS consolidates all the comments and reviews them with the PI. The PM and EM should try to identify the engineering feasibility issues based on the science requirements summary table in the preliminary SRD. Although not essential, it may be advantageous to resolve some of the most critical engineering feasibility issues before the SCR through, for example, analysis or laboratory breadboards and tests. The PS should work with the PI and NASA management to set a tentative date for the SCR.

Four Months Prior to SCR: (Block 35)

The PS sends the SCR agenda (listed in Appendix C) to the PI, and identifies a list of crucial technical items, e.g., breadboard results, primary science requirements, etc., that the PI should be prepared to present at the Science Concept Review. Most of the information presented at the SCR by the PI must come from the Preliminary SRD.

Three Months Prior to SCR: (Blocks 26, 31, and 32)

The experiment scope and feasibility issues of the science concept must be resolved by this time (usually through breadboard tests and analyses). The SCR cannot occur until this is complete. The PS generates a list of at least four potential peer reviewers, (the PI may have some suggestions) to serve as Science Review Panel members, and passes it along to the Enterprise Discipline Scientist at HQ. The EDS selects the Science Review Panel and is not limited by this list. The PS assists the EDS in scheduling the SCR by providing information on the availability of the PI and the relevant GRC staff. The PS or his/her delegate needs to provide the name and affiliation of the PI and Science Review Panel members to the National Center for Microgravity Research (NCMR) personnel who will provide support to the PS. Failure to do so may cause significant logistical problems shortly before the review. (In the case of a non-US citizen or non-permanent US resident, a NASA C-216 Non-U.S. Citizen Access Request Form must be completed and sent to the Security Branch at least 30 days prior to the onsite visit.)

The NCMR will provide the following assistance to NASA as stated in NCC3-544, modification 6, “[Task 10]: Provide administrative, logistical and clerical support to NASA GRC in the planning and conduct of selected project review panels. Arrange for the attendance at the reviews of experts from outside of NASA and the NCMR, but selected by NASA, and provide for their travel, accommodations, presence at GRC and orientation. When necessary, as defined by NASA, make arrangements for meeting rooms, audio visual equipment, local transportation, mailings of meeting materials, group meals, and miscellaneous supplies. Provide for compensation and travel reimbursement for review panel members as appropriate and in accordance with Federal and USRA travel regulations."

Two Months Prior to SCR: (Blocks 33 and 34)

If the PI has never been through an SCR, he or she should plan to give a SCR dry-run at GRC to the PS, EM, PM, Microgravity Research management, engineering team and other appropriate personnel. The PI revises the SCR presentation based on comments. The PS, EM, PM and engineering team then evaluate the maturity of preliminary science requirements, and the resolution and closure of all science concept feasibility issues (e.g., new measurement methods, the justification of long duration microgravity, etc.) in preparation for the SCR. If the PS is to present material at SCR, he/she must prepare the information at this time. The PM or PS or their delegate reserves a conference room for the SCR.

Three Weeks Prior to SCR: (Blocks 30, 35-37)

The PM prepares a SCR presentation package which consists of the engineering feasibility issues to RDR, the schedule and budget to RDR, and a rough order of magnitude schedule and budget for the duration of the project. (Please see item 9 of Appendix C). The PS receives the second draft of the Preliminary SRD and a final draft copy of SCR presentation from the PI. The PM's presentation package and the SCR introductory charts (please see Appendix G) are added to the PI's portion to complete the draft SCR package. The PS and PM review the entire SCR package with the Discipline Program Manager and first line supervisors. When both presentations are acceptable, the PS or PM sends these documents, and a cover letter (an example is given in Appendix F), to the Science Review Panel, the PI and Enterprise Discipline Scientist.

The PM also prepares a draft ISS Mission Evaluation Request (MER). The ISS MER contains preliminary payload requirements that includes, but is not limited to, the (1) outfitting mass and volume, (2) steady state per run resources/accommodations/ supporting services, and (3) scale of payload development with an operations concept. Please see the MSD Payload Planning Process document (GRC-W6700.014) for more details.

Two Weeks Prior to SCR: (Block 36)

The following tasks are the responsibility of the Project Manager and the Project Scientist or their delegates (the NCMR may be willing to provide assistance with some of these tasks):

* Reserve security badges for PI, Co-I, other members of the PI's team, and the Science Review Panel.

* Arrange for the PI and Panel Members to have transportation to GRC, prior to the start of the meeting. On the morning of the SCR, reconfirm that the driver will be bringing the panel members to GRC.

* Arrange transportation for the PI and the Panel when the SCR adjourns.

* Remind the Science Review Panel Chairman to produce a written draft of the Panel's letter of recommendation the same day that the SCR is held. (NASA may need to provide a computer). Retain a copy of the draft. Remind the panel that they shall be required to give a verbal presentation of their review findings to the PI and all those in attendance at the conclusion of the SCR meeting.

* Reserve a conference room for the Science Review Panel caucus (about one to two weeks before SCR).

* Arrange for the availability of equipment needed for the PI's presentation, e.g. video, two overhead projectors, pointer, etc.

* Have name place labels (tags) made for the Science Review Panel, PI, Co-I, EDS, Microgravity Research Management at Glenn, PS, DPS, PM, and EM.

* Receive final SCR package from PI at least three days before the review. Assemble complete SCR package which consists of: introductory charts, PI presentation and PM presentation.

* Prepare copies of the SCR packages (around 30) and the SRD (about 5).

* Send an email to the appropriate division personnel reminding them of the SCR two days before the review.

* Verify with the NCMR that panel member's travel plans are made.

* Try to accommodate the special needs, if any, of the PI, Co-I, and Science Review Panel members.

* Keep the number of people attending the SCR to a manageable level: request attendance by only those people who are necessary for the review. This may include people who are new to the process and wish to view an SCR.

* Check conference room; ensure that all the equipment is ready and functioning (e.g., video and projector); get key for equipment cabinet if needed.

* Arrange for any hardware displays, refreshments, etc.

* Set up the conference room the day before the review. Arrange seating so the Science Review Panel members are together. The EDS should be at the head of the table.

The Day of the SCR: (Blocks 38-45)

The SCR requires one full day and is conducted by the Enterprise Discipline Scientist (EDS) with significant preparation support from the Project Scientist and Project Manager. The PI's presentation lasts 3 to 5 hours and the PM's is typically 1/2 to 1 hour. The EDS facilitates the science review panel caucus with the PS attending to answer questions about the experiment. After the caucus, the Science Review Panel gives an oral presentation of their findings to the PI, EDS, PS, PM, and engineering team and anyone else attendance. Following the presentation the Chairman produces a written draft and submits it to the PS.

One Day after the SCR:

It is useful to hold a meeting with the PI, (if he or she can stay an extra day) PS, PM, EM and the engineering team the day after the SCR to assess the draft version of the Science Review Panel's letter of recommendation. The goal of the meeting is to divide the tasks between the PI and the project team.

6.5 SCR OUTCOME

About One Month after SCR: (Block 46)

The Science Review Panel submits their consensus letter of recommendation to the Enterprise Discipline Scientist at HQ concerning the future direction of the project, such as enlarging, modifying or descoping the proposed effort. This letter usually discusses the value of the proposed science to the peer community. It should contain a recommendation for or against space flight for the conduct of the proposed experiment. It usually identifies additional experimentation and analysis that the panel recommends for performance prior to RDR.

About Three Months after SCR: (Block 47)

The Microgravity Research Division Director (MRD) will review the Panel's letter to determine if the project has significant scientific merit and write an evaluation letter to the Microgravity Research Program Office (MRPO). If the project has significant scientific merit, this letter emphasizes particular recommendations from the Science Review Panel that the MRD feels are most important. If there is little or no significant scientific merit, the MRD will not recommend continuation of the experiment as a flight project.

About Four Months after the SCR: (Blocks 48-56)

If the MRD has found the experiment to have significant scientific merit, the MRPO will determine if there are sufficient resources available to accommodate the investigation. If funds are available, the MRPO Manager will send a written evaluation to the PI as follows:

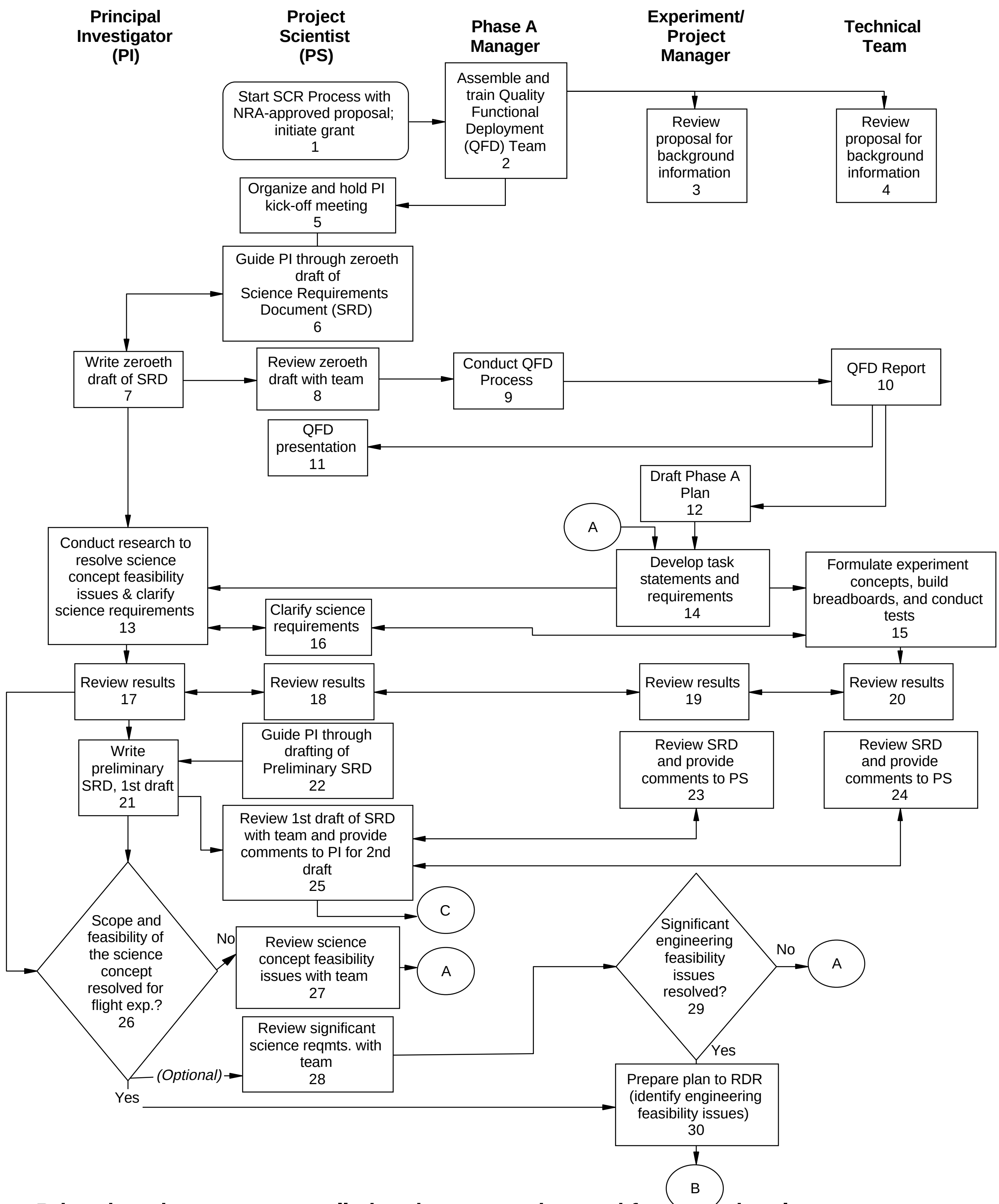
i. MRPO sends a letter to the PI issuing the Authority To Proceed (ATP) to the next phase of the project (RDR) with the potential provision that some, or all, of the Science Review Panel recommendations and changes be implemented in the SRD, and/or Project Plan, through laboratory testing and/or analyses prior to RDR.

If the MRD has found the experiment to have little or no scientific merit and/or the MRPO has determined that the funds are insufficient, then the MPRO manager will send a written evaluation to the PI as follows:

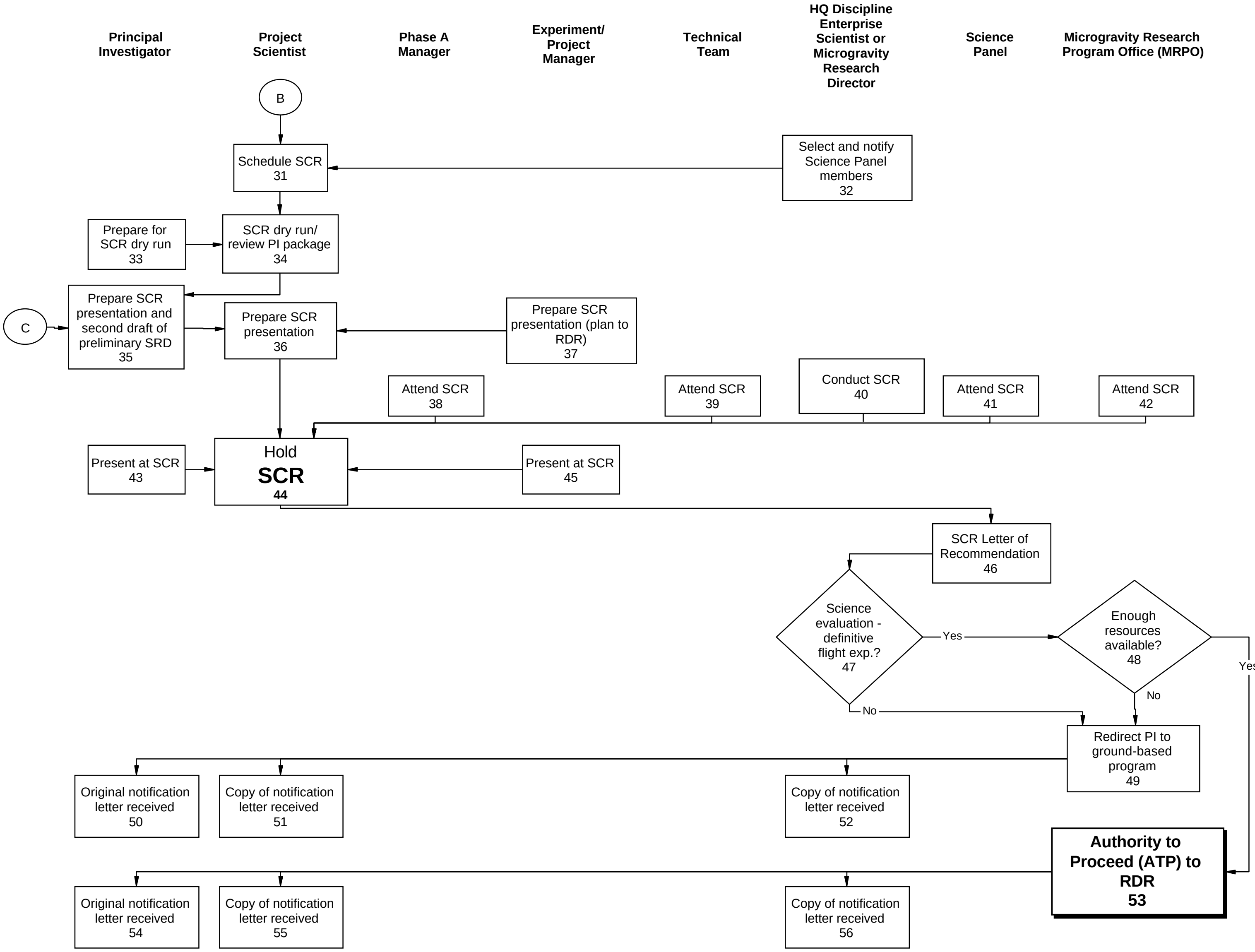
ii. MRPO sends a letter to the PI directing him/her to continue the research as a ground-based experiment. Ground-based funding will continue for the period of performance for the current grant (usually 4 years).

It is important to retain a copy of the Science Review Panel letter, the MRD Director's letter, and the MRPO Manager's letter. If the project is authorized to proceed to RDR, the PS and PM may need to periodically refer to these letters.

7.0 FLOW DIAGRAMS - Science Concept Definition Process to SCR



7.0 FLOW DIAGRAMS - Science Concept Definition Process to SCR



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APPENDIX A

ACRONYMS

Co-I	Co-Investigator
DPS	Deputy Project Scientist
EM	Experiment Manager
EDS	Enterprise Discipline Scientist
GRC	Glenn Research Center at Lewis Field
HQ	Headquarters
ISS	International Space Station
MRD	Microgravity Research Division at HQ
MRPO	Microgravity Research Program Office
MSAD	Microgravity Science and Applications Division
MSD	Microgravity Science Division at GRC
NCMR	National Center for Microgravity Research on Fluids and Combustion
NRA	NASA Research Announcement
PI	Principal Investigator
PM	Project Manager
PS	Project Scientist
QFD	Quality Function Deployment
RDR	Requirements Definition Review
SCF	Science Concept Formulation
SCR	Science Concept Review

APPENDIX B

DEFINITION OF SCIENCE REQUIREMENTS

The requirements for the flight investigation are defined in terms of science requirements. These requirements should be discussed in detail in the body of the SRD and should be summarized in a Science Requirements Summary Table, (as shown in the example provided in Table 1 of Appendix H). The comparison of the detailed requirements with those in the table is facilitated if the text discussion follows the table with section heading that match sections of the table. The purpose of the science requirements is to provide the engineering team with the information they need to define the hardware requirements and to provide the science review team with the information they need to determine if the measurements will achieve the scientific goals of the approved investigation. In general the PI knows more about the science of the measurements they want and the engineering team knows more about the feasibility of implementing various technologies in flight hardware. The PI specifies in the most fundamental terms possible what is to be measured or controlled and the engineering team determines how to implement the requirement. Ideally the SRD should contain only requirements in fundamental science terms (with pass/fail criteria that can be used to define the hardware) and all design and implementation should be left to the project team. However, due to the distribution of skills and knowledge, PI experience base, and the fundamental difficulty of specifying some requirements, some deviation from this model will occur. The various ways to provide requirement specifications are listed below.

1. Fundamental specifications

   Identify the parameter being measured or controlled and the

   a. measurement sensitivity, accuracy and repeatability
   b. spatial and temporal resolution, accuracy, and frequency (sampling rate and number of measurements per unit spatial dimension)
   c. spatial and temporal domain (field of view or length of experiment)

   and any other specifications appropriate to the parameter being measured or controlled. These requirements must be individually traceable to the approved objectives and supporting modeling/analysis. In principle, this is all that is required to specify a requirement. Concessions in other requirements to achieve this requirement should be stated (blocked view, holes etc.) The fundamental requirements should not specify a technology (see item #3).

Approach Number 1 should be attempted for all requirements. In cases where this is not possible the two alternate methods below should be considered.

2. Functional Specifications (not preferred)

   If the requirement is truly functional in nature (i.e. the hardware must produce some desired but hard to quantify result) an alternate approach is to specify 1-g tests which can be used for acceptance testing of the engineering design. The acceptance criteria must be objective and quantitative. Use of low-g testing for a functional specification of this sort can be considered if the project deems it feasible. Functional specifications of this sort must be individually traceable to the approved objectives and supporting modeling/analysis. An example of a functional requirement is the imaging of a low gravity flame that has not been previously studied so luminance and spectral data are unavailable. In this case, the camera sensitivity requirement might be defined in terms of a being able to image a particular dim flame produced in low gravity testing which the PI believes will be comparable to what will be seen in flight.

3. Optional Description/design information

   To simplify the project team's work, it is natural for the PI to suggest a proposed approach. Included in this proposal can be the assumption of verification of requirements by the PI. (i.e. build it this way and I will assume the temporal resolution analysis). This description can be as detailed as desired but does not replace Item #1. If there is inherent difficulty in the requirement, it is helpful for the PI to provide design approaches but the project team has the option of pursuing other designs that they can show meet the fundamental or functional requirements (# 1 or #2). An example would be for thermocouple measurements: "use wire of diameter x and distance from sheath to bead of y and coating properties z and the P.I. will assume responsibility for radioactive corrections and temporal response issues".

4. Optional enhancements ("desirements")

   The P.I. must carefully limit the items that are declared to be requirements but it is appropriate to include desired enhancements that the project team will consider including if possible.

Items that are in reality operational suggestions and hardware reliability suggestions should be treated as such and not be included in the science requirements. For example, monitoring the laser power is an operational suggestion, the fundamental requirements is to deliver laser energy whose power level is know within x%. Likewise verification or on orbit testing of hardware are operational suggestions if the data from the testing is not normally needed for the science data analysis.

Science requirement specification, detailed suggestions:

Typically problems occur in the final verification of flight experiments because science requirements were poorly defined. These can usually be covered by waivers or a memorandum of understanding, but the following suggestions can help to avoid mistakes.

Range:

> Range should be specified in terms of what is actually needed not in terms of typical instrument ranges. The minimum range should not be zero but the minimum accuracy needed. Accuracy should be in terms of percent of reading not % of full scale since the scale of the instrument is not known at the time the requirement is specified. Accuracy should be stated in end to end terms and be what is really needed and not a value picked from a catalog on hand

Concentrations:

> Confusion often occurs over how to specify the accuracy of a concentration requirement, suggested language is either % of concentration or absolute, i.e.

To specify a range from19% to 21% it could be either

20% +/- 1% (absolute) or 20% +/- 5% of concentration.

In the case of gas mixtures, another common usage instead of "absolute" is "mol percent."

Dave L. Urban, Chief
Microgravity Combustion Science Branch

APPENDIX C

CONTENT OF THE SCIENCE CONCEPT REVIEW

i. Welcome (GRC Microgravity Science Division Representative)

ii. Instructions to Science Review Panel (NASA Enterprise Discipline Scientist)

0. Executive Summary (PI)
1. Goals/Objectives
2. Proposed Space Experiment (concept diagram)
3. Benefits (potential application)

1. Introduction and Background (PI)
1. Description of Science
2. Brief Historical Overview of Science
3. Currently Active Research
4. Current Status of Understanding and Statements of Key Issues in the Field
5. Gaps in Understanding this Experiment Plans to Fill

2. Research Related to Proposed Space Experiment (PI)
1. Experiments - 1g Laboratories, Drop Towers, and Aircraft
2. Models - Numerical and Analytical

3. Proposed Space Experiment (PI)
1. Objective and Hypothesis of Proposed Investigation
2. Benefit to Science and Technology
3. Description of Experiment Concept (Cartoon and Block Diagrams)
4. Anticipated Results

4. Justification for Extended Duration Microgravity Environment (PI)
1. Limitations of Terrestrial (1-g laboratory) Testing
2. Limitations of Drop Towers and Aircraft
3. Need for Accommodations in the Space Station, Space Shuttle or Sounding Rocket
4. Limitations of Modeling Approaches

5. Detailed Flight Experiment Description (PI)
1. Individual Science Requirements, Prioritized Desires, and Rationale
2. Test Matrix
3. Success Criteria (minimum and complete)
4. Data Archiving Plan

6. Use of Data Obtained from Proposed Space Experiment (PI)
1. Data Reduction and Analysis
2. Model or Hypothesis Verification

7. Science Plan to RDR (PI)
1. Identify Critical Tasks and Plans for Resolution
2. Other Science Activities (ground-based experimentation, modeling, etc.)

8. Summary (PI)

9. Engineering Plan to RDR (PM)
1. Identify Critical Engineering Feasibility Issues
2. Develop Plan for Resolution of Engineering Feasibility Issues
3. Develop Schedule and Budget

10. Rough Order of Magnitude Schedule and Budget to Flight (PM)

11. Science Review Panel Caucus (PS to attend as an observer and answer questions)

12. Science Review Panel Feedback to Everyone

13. Concluding Remarks (NASA Enterprise Discipline Scientist)

APPENDIX D

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3.4 Limitations of Modeling Approaches

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5.4.2 Location and Number of Sensors

5.4.3 Sampling Rate

5.5 Pressure Measurement and Control

5.6 Flow Rate

5.7 Imaging

5.7.1 Type

5.7.2 Frame Rate

5.7.3 Field of View and Resolution

5.7.4 Depth of Field

5.7.5 Number, Orientation of Cameras

5.8 Environment

5.9 Acceleration - Magnitude, Direction, and Frequency Range

5.10 Astronaut Involvement and Experiment Activation

5.11 Telepresence

5.12 Postflight Data Deliverables

5.13 Success Criteria

5.13.1 Minimal Success

5.13.2 Significant Success

5.13.3 Complete Success

6.0 REFERENCES

7.0 APPENDIX - EXPERIMENT DATA MANAGEMENT PLAN (EDMP)

(Reference GRC-W6700.011)

APPENDIX E

Signature Page For The Science Requirements Document

Title of Experiment:

Date:

Revision:

Principal Investigator	Signature	Date

PI's Address:

CONCURRENCES

NASA Glenn Research Center:

Project Scientist	Signature	Date
Project Manager	Signature	Date
Discipline Lead Scientist	Signature	Date
Discipline Program Manager	Signature	Date

NASA Headquarters:

Enterprise Discipline Scientist	Signature	Date

APPROVAL

Enterprise Lead Scientist	Signature	Date

APPENDIX F

SCR COVER LETTER
TO THE SCIENCE REVIEW PANEL

6712 **August 5, 1998**

TO: Distribution

FROM: UG/Enterprise Scientist for Fluid Physics

SUBJECT: Science Concept Review (SCR) for The Experiment Entitled **"A Mechanistic Study of Nucleate Boiling Heat Transfer Under Microgravity Conditions"**

Thank you for agreeing to participate in the Science Concept Review (SCR) of **"A Mechanistic Study of Nucleate Boiling Heat Transfer Under Microgravity Conditions".** The review is scheduled for **September 1, 1998, starting at 8:00 a.m.** at the NASA Glenn Research Center (GRC), Cleveland, Ohio, in the **Developmental Engineering Building (DEB), Room 3102**. A tentative agenda is enclosed.

The purpose of the SCR is to affirm the merit of and need for the experiment, establish the detailed scientific objectives, review the preliminary science requirements, verify the need for a microgravity experiment and demonstrate that all science concept feasibility issues have been resolved.

To facilitate a timely decision, I am requesting you to attempt to generate the first draft of your report before leaving the GRC. This will provide me with timely information to direct the activities of the project team in a cost effective manner. Please plan your travel accordingly. I will also need your final report within 30 days after the review to meet my commitments.

Enclosed you will find a SCR presentation package, the Preliminary Science Requirements Document (SRD), a map to NASA Glenn Research Center, and listing of surrounding restaurants. Included in the SCR package is a tentative agenda, a list of Science Review Panel Members and appropriate NASA contacts, and the Science Review Panel Charter.

Please feel free to contact the Project Scientist, **Dr. David Chao at (216) 433-8320**. You may also contact **Ms. Christina Klamer at (216) 433-5901** for logistical details. Questions regarding travel accommodations and reimbursement for the Science Review Panel Members are being handled by **Ms. Christine Gorecki** who can be reached at **(216) 433-2581**.

I look forward to seeing you at the review.

Gerald A. Pitalo

3 Enclosures

Distribution: (Science Review Panel Members)
Georgia Institute of Technology/S. Abdel-Khalik
University of Pennsylvania/P. Ayyaswamy
Texas A&M University/G. Peterson
NASA Glenn Research Center/R. Siegel

cc: (w/ encls.)
6000/J. A. Salzman (w/o encls.)
6700/S. N. Simons (w/o encls.)
6700/F. J. Kohl
6700/H. D. Ross
6712/F. P. Chiaramonte
6712/D. F. Chao
6712/B. S. Singh
6728/J. M. Hickman
6728/N. J. Shaw
HQ/UG/B. M. Carpenter
HQ/UG/A. D. Pline
Dynacs/R. Ziegfeld

bcc:
6700/Division File
6712/Official File

6712/DFChao;cck;7/23/98;NucleateBoiling_SCR_memo

APPENDIX G

SCIENCE CONCEPT REVIEW INTRODUCTORY CHARTS

- Title Page
- Agenda
- Science Review Panel List
- NASA Contacts
- SCR Science Review Panel Charter

The example formats to follow……..(*Note that text in bold is information that will change per experiment)

APPENDIX G (Example)

A Mechanistic Study of Nucleate Boiling Heat Transfer Under Microgravity Conditions

as proposed
by Principal Investigator:

Prof. Vijay K. Dhir
University of California, Los Angeles

Dr. Mohammad M. Hasan
NASA Glenn Research Center

September 1, 1998

APPENDIX G (Example)

Typical SCR Agenda

7:30 am	Check-in, coffee and donuts	
8:00 am	Welcome	**Howard Ross** (Rep.)
8:10 am	Charge to Science Review Panel	**Gerald A. Pitalo** (EDS)
8:30 am	Science Presentation	**Vijay K. Dhir** (PI)
	Introduction, Review	
10:30 am	Break	
10:45 am	Justification for Microgravity, Experiment	
	Plan, Science Requirements	**Vijay K. Dhir** (PI)
12:00 pm	Lunch	
1:00 pm	Engineering Plan to the Requirements	
	Definition Review (RDR)	**J. Mark Hickman** (PM)
1:30 pm	Science Review Panel Caucus	Panel
4:00 pm	Science Review Panel Feedback to Everyone	
4:30 pm	Concluding Remarks	**Gerald A. Pitalo** (EDS)
5:00 pm	Adjourn	

APPENDIX G (Example)

<u>Science Review Panel Members</u>

Prof. Said I. Abdel-Khalik
Georgia Institute of Technology
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gpp5386@teesmail.tamu.edu

Dr. Robert Siegel
NASA Glenn Research Center
Research and Technology Directorate
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Cleveland, OH 44135
Ph.: (216) 433-5831
Fax: (216) 433-8581
Robert.Siegel@grc.nasa.gov

APPENDIX G (Example)

NASA Headquarters Contacts

Microgravity Research Division Director	**Robert C. Rhome**	**(202) 258-1490**
Lead Enterprise Scientist	**Bradley M. Carpenter**	**(202) 358-0826**
Enterprise Scientist for Fluid Physics	**Gerald A. Pitalo**	**(202) 358-0827**

NASA Glenn Research Center Contacts

Fluid Physics Discipline Scientist	**Bhim S. Singh**	**(216) 433-5396**
Fluid Physics Discipline Program Manager	**Fred J. Kohl**	**(216) 433-2866**
Fluid Physics Flight Projects Branch Chief	**Nancy J. Shaw**	**(216) 433-3285**

Project Contacts

Principal Investigator	**Vijay K. Dhir**	**(310) 825-8507**
Co-Investigator	**Mohammad M. Hasan**	**(216) 977-7494**
Project Scientist	**David F. Chao**	**(216) 433-8320**
Project Manager	**J. Mark Hickman**	**(216) 433-7105**

APPENDIX G (Example)

Science Review Panel Charter

- The significance of the problem being investigated including the benefits that the experimental and theoretical results would provide to the research community and industry.
- The maturity of the overall scientific investigation.
- The scientific objectives of the proposed flight experiments.
- The need for a microgravity environment to achieve the proposed scientific objectives.
- The priorities of these scientific objectives.
- The rigor with which the proposed flight experiment has been conducted terrestrially (e.g. influence of gravity, reproducibility and quantification of experimental conditions and results, modeling, application/verification of current and/or developing theoretical framework etc.).
- The scientific specifications for the proposed flight experiments as expressed in the preliminary draft of the Science Requirements Document.
- The conceptual design for the apparatus and whether this design could be expected to deliver a level of performance that allows the scientific objectives to be achieved.
- Technology issues that would prevent a timely, successful achievement of the scientific objectives.

APPENDIX H

Zeroeth Draft - Example

Preliminary
Science Requirements Document

For

Equiaxed Dendritic Solidification Experiment

(EDSE)

Zeroeth Draft

March 1997

Christoph Beckermann: Principal Investigator; U. Iowa

Henry C. deGroh III: Co-Investigator; NASA Glenn Research Center

Ingo Steinbach: Co-Investigator; Access, RWTH Aachen, Germany

Alain Karma: Co-Investigator; Northeastern U.

Department of Mechanical Engineering

The University of Iowa

Iowa City, IA 52242-1527

APPENDIX H

Signature Page for
Microgravity Science Division
Science Requirements Document (SRD)

Title of Experiment: Equiaxed Dendritic Solidification Experiment
Date: March 1997
Revision: 0

Christoph Beckermann ______________________________ ______________
Principal Investigator Signature Date

Department of Mechanical Engineering
University of Iowa
Iowa City, IA 52242-1527

CONCURRENCES
NASA Glenn Research Center

Francis P. Chiaramonte — Signature — Date
Project Scientist

Diane Malarik — Signature — Date
Project Manager

Bhim S. Singh — Signature — Date
Discipline Lead Scientist

Fred J. Kohl — Signature — Date
Discipline Program Manager

NASA Headquarters

Michael J. Wargo — Signature — Date
Enterprise Discipline Scientist

APPROVAL

Bradley M. Carpenter — Signature — Date
Enterprise Lead Scientist

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5.7.3 Field of View and Resolution

5.7.4 Depth of Field

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6.0 REFERENCES

7.0 APPENDIX - EXPERIMENT DATA MANAGEMENT PLAN (EDMP)

(Reference GRC-W6700.011)

APPENDIX H

EXECUTIVE SUMMARY

A microgravity experiment is planned to study the microstructural evolution of and thermal interactions between several equiaxed crystals growing dendritically in a supercooled melt of a pure and transparent substance under diffusion controlled conditions. The existing Millikelvin Thermostat (MITH) will be modified by replacing the single stinger with four stingers (representing nucleation sites), allowing for the growth of up to four equiaxed crystals towards each other. The measurements will consist of the transient evolution of the velocities of the primary and secondary dendrite arm tips, internal dendrite structures, selected temperatures, and volume change, for a range of initial supercoolings. The microgravity benchmark data will be compared to corresponding ground-based experimental data to quantify the influence of gravity induced convection on dendrite growth and interaction mechanisms. Numerical simulation of the experiment will allow for the extraction of additional data from the measurements. The data will be used for the testing of existing equiaxed solidification theories and the development of refined models for the simulation of microstructure formation in castings.

The planned microgravity experiment extends the measurements of Glicksman and coworkers for the operating state of a single, isolated dendrite tip (IDGE) to the case of multiple, interacting crystals. The general scaling theories and models of the growth kinetics and evolution of morphological parameters for the growth in an infinite melt do not apply to the case of interacting crystals, and benchmark data are needed for the testing of more applicable or refined models. Furthermore, the interacting regime cannot be described by coarsening theories, which are primarily applicable after tip growth has ceased. Only the study of the growth interactions can explain the variations in microstructure observed in cast materials, ranging from globulitic to equiaxed dendritic, and allow for the prediction of their occurrence as a function of crystal density and available supercooling. The understanding of the growth of an assemblage of equiaxed crystals is therefore of key importance in selecting process conditions that optimize the structure and properties of cast materials.

APPENDIX H

The available experimental data on equiaxed dendritic solidification is very limited, with only some bulk solidification experiments conducted (on earth) using metal alloys. The data are of limited use because of (i) the inability to control and quantify nucleation, (ii) the presence of uncontrolled, gravity-driven melt convection and settling/floating of crystals, (iii) the difficulty to observe growth in metallic systems, and (iv) the complications associated with coupled thermal and solutal fields when using alloys. The proposed experiment is designed to be simple, yet overcomes all of these limitations. In particular, gravity-driven convection can only be minimized in a long-duration microgravity environment. The study of the growth interactions in the pure diffusion limit is critical for the unambiguous quantification of the thermal environment during growth and the testing of the available theories. Melt convection would not only complicate the heat transport problem, but also limit the experiment to conditions where accurate measurements are not possible.

Experiment Objectives

The objective of the research program is to quantitatively determine and understand the fundamental mechanisms that control the microstructural evolution during equiaxed solidification. The objective of the microgravity experiment is to study the microstructural evolution of and thermal interactions between several equiaxed crystals (up to 4) growing dendritically in the supercooled melt of a pure and transparent metal analog material (SCN) under strictly diffusional heat flow conditions. The approach of this space experiment is to determine the transient evolutions of the primary and secondary dendrite tip speeds, the internal dendrite morphology and solid fraction, and the temperature field in the melt for a range of initial supercoolings and, thus, interaction "strengths" between the crystals. Corresponding ground-based experiments will be conducted to ascertain the influence of melt convection. The experiments will be simulated numerically, without resolving all structural details internal to the crystals (i.e., mesoscopic simulations), in order to completely characterize the thermal field in the supercooled melt around the crystals. The data will primarily be used to test theories of equiaxed solidification and to develop refined and/or new theories. Direct numerical simulations on a microscopic scale will be conducted, within the limited range of conditions presently achievable, to supplement the experimental data and allow for further testing of available theories. Simplified models that describe, in an average sense, the growth and latent heat evolution of interacting equiaxed crystals in a representative elementary volume or unit cell, will also be developed for use in the simulation of equiaxed dendritic solidification at the scale of a casting.

APPENDIX H

Table 1: EDSE Science Requirements Summary Table

Parameter	Section	Requirement
Test Fluid (Material)	5.2	99.999% pure SCN, to be maintained through processing
Supercooling	5.2	0.1 to 1.0 K, accuracy ± 2% of supercooling
Growth Chamber	5.3	
Walls		Back solidification on the chamber wall to be limited to the stingers.
Nucleating Stingers		Four (4) independently nucleating stingers. Active stingers emerging simultaneously to within +/- 10% of total solidification time - about +/- 4sK^2/ supercooling^2. One crystal per stinger is desired.
Positioning of stingers		Four stingers at the corners of a tetrahedron directed towards the center with tip separation distance of 10 mm. Minimum tip to wall distance of 20 mm.
Volume change		Accommodate all volume changes over temperature range 15 C to 65 C within the SCN without causing the formation of bubbles in the liquid SCN.
Temperature Measurement and Control	5.4	
In the Growth Chamber: Accuracy and response rate		+/- 0.002 K; the desired time response is 1 sec. or less.
Number of temperature sensors		Two (2) near field, centered between stingers while not obstructing views, and one (1) far field.
Save rate		Save four per min., then after dendrite initiation, save at 1 Hz/K times supercooling.

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Parameter	Section	Requirement
Bath Temperature and Control		Measured and controlled to within +/- 0.002 K; temperature sensor time response 3 sec. or less. Save at the same rate as chamber temperature sensors.
Imaging	5.5	
Type and Rate		High-resolution analog or digital imaging system, 50 frames/run per view minimum; capability to adjust time interval between frames for each run.
Imaging volume		Approximately 15 mm x 15 mm x 15 mm, centered.
Resolution		Resolution adequate to measure within imaging volume, the primary dendrite tip velocities to within +/- 5% for a supercooling range from 0.1 to 1K and tip radii to within +/- 5% for 0.1 to 0.7K and +/- 10% for 0.7 to 1K.
Number, orientation of cameras		Four views into the chamber along 2 orthogonal lines of sight; a fifth view, orthogonal to the others, is also desired.
Acceleration or (Vibration and g- jitter)	5.6	During growth, all accelerations maintained at $g< 10^{-4}\, g_0$ at frequencies < 0.5 Hz and $g<10^{-3} g_0$ at frequencies > 5 Hz. Accelerations measured in the vicinity of the experiment, with a minimum bandwidth range of 0 to 100 Hz, and accuracy of +/- 20%. Time tagged notification of accelerations outside specified levels.
Astronaut Involvement	5.7	Crew involvement required is activation and deactivation of the experiment.
Telepresence	5.8	Capability to adjust test parameters via commanding during flight, including supercooling, number of stingers activated, duration of each stage, image timing, bath stabilization, and data save rate. Down link of data, including all bath and chamber temperatures and selected images from each of the orthogonal views.

APPENDIX H

Table 2: EDSE Test Matrix

(a) Primary Test Matrix (to meet the complete success criteria)

Experiment Set	Number of stingers activated	Range of supercooling (K)	Supercooling increment (K)	Runs at each supercooling	Total number of runs
1	4	0.1 to 1.0	0.1	4	40
2	2	0.9 to 0.1	0.2	3	15
3	1	0.1 to 0.7	0.2	2	8
					Total: 63

(b) Secondary Test Matrix (to be conducted if time permits)

Experiment Set	Number of stingers activated	Range of supercooling (K)	Supercooling increment (K)	Runs at each supercooling	Total number of runs
4	4	1.0 to 0.2	0.1	3	27
5	4	0.18 to 0.06	0.04	3	12
6	2	0.1 to 1.0	0.1	2	20
7	1	1.0 to 0.2	0.2	2	10
					Total: 69

Post-Flight Data Deliverables

The following deliverables must be supplied by NASA to the PI for post-flight analysis:

- Time-synchronized record of **experimental parameters** including supercooling and which and when stingers are activated.
- Time-synchronized digitized **images** from all 4 (or 5) cameras during crystal growth.
- Time-synchronized **temperature** data from the three sensors in the growth chamber and from the sensor in the bath during crystal growth, plus values before growth.
- Time-synchronized three-axis **acceleration** data in the vicinity of the experiment.
- Complete flight **experiment timeline** record for EDSE.